MOUNTAIN EVAPORATION

DATA FROM THE SAN DIMAS EXPERIMENTAL FOREST

BY LYLE F. REIMANN

MISCELLANEOUS
PAPER No. 35
JULY 1959

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY --- CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

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Studies reported here were conducted in cooperation with

STATE OF CALIFORNIA
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THE AUTHOR: Lyle Reimann has been a member of the San Dimas Experimental Forest staff since 1938. For the past 10 years he supervised the compilation of all climatic, hydrologic and related records. Prior to his present assignment he was a member of the field staff on the experimental forest.

MOUNTAIN EVAPORATION

Data from the San Dimas Experimental Forest at Elevations of 1,500 to 5,100 Feet

Lyle F. Reimann

Great amounts of water are lost for human and other biological use by evaporation. This loss occurs from many types of surfaces, including soil, vegetation, and free water. Measurement of these losses, however, is relatively difficult except from a free water surface. Therefore, extensive measurement of this particular evaporation process is in progress throughout the world. Although free water surface evaporation measurements cannot be applied directly to determine quantitative losses from reservoirs, plants, or soils, they serve as useful regional indexes. Evaporation data representing monthly summaries of loss of water from a free water surface are presented in this publication. The measurements were made at four elevations, all in chaparral openings with southerly exposures on the San Dimas Experimental Forest, in the front range of the San Gabriel Mountains of southern California.

The San Dimas Experimental Forest was established in 1933 as a brushland watershed management research field laboratory. Research objectives are to determine how watersheds function, and to develop methods of watershed management that will insure the maximum yield of usable water with the minimum of sedimentation and flood hazard. Fundamental to these objectives, inventories of local climate were made at four climatic stations. These stations were located at several elevations on the experimental area (fig. 1), and were equipped with instruments to obtain measurements of evaporation and other climatic records (table 1).

The following evaporation data are mostly from U. S. Weather Bureau type evaporation pans 4 feet in diameter and set above ground level. In addition, data are given from San Dimas pans set 18 inches in the ground at two locations.

Table 1.--Equipment at climatic stations, San Dimas Experimental Forest

Item	San Dimas Canyon	Tanbark Flat	San Gabriel Divide	Fern Canyon
Louvered instrument shelter	x	x	x	x
Maximum and minimum thermometers	x	x	x	x
Hygrothermograph	x	x	x	x
Whirling type psychrometer	x		x	x
Aspirating psychrometer		x		
Taylor shallow black pan evaporimeter		x		
Weather bureau type evaporation pan	x	x	x	x
San Dimas evaporation pan	x	x		
Anemometer at 18-inch elevation, continuous recording	x	x		
Anemometer at 7-foot elevation, continuous recording	x	x	x	x
Anemometer at 30-foot elevation, continuous recording		x		
Wind direction transmitter	x	x	x	x
Soil temperature thermometers and thermograph	x	x	x	x
Recording and non-recording rain gages	x	x	x	x

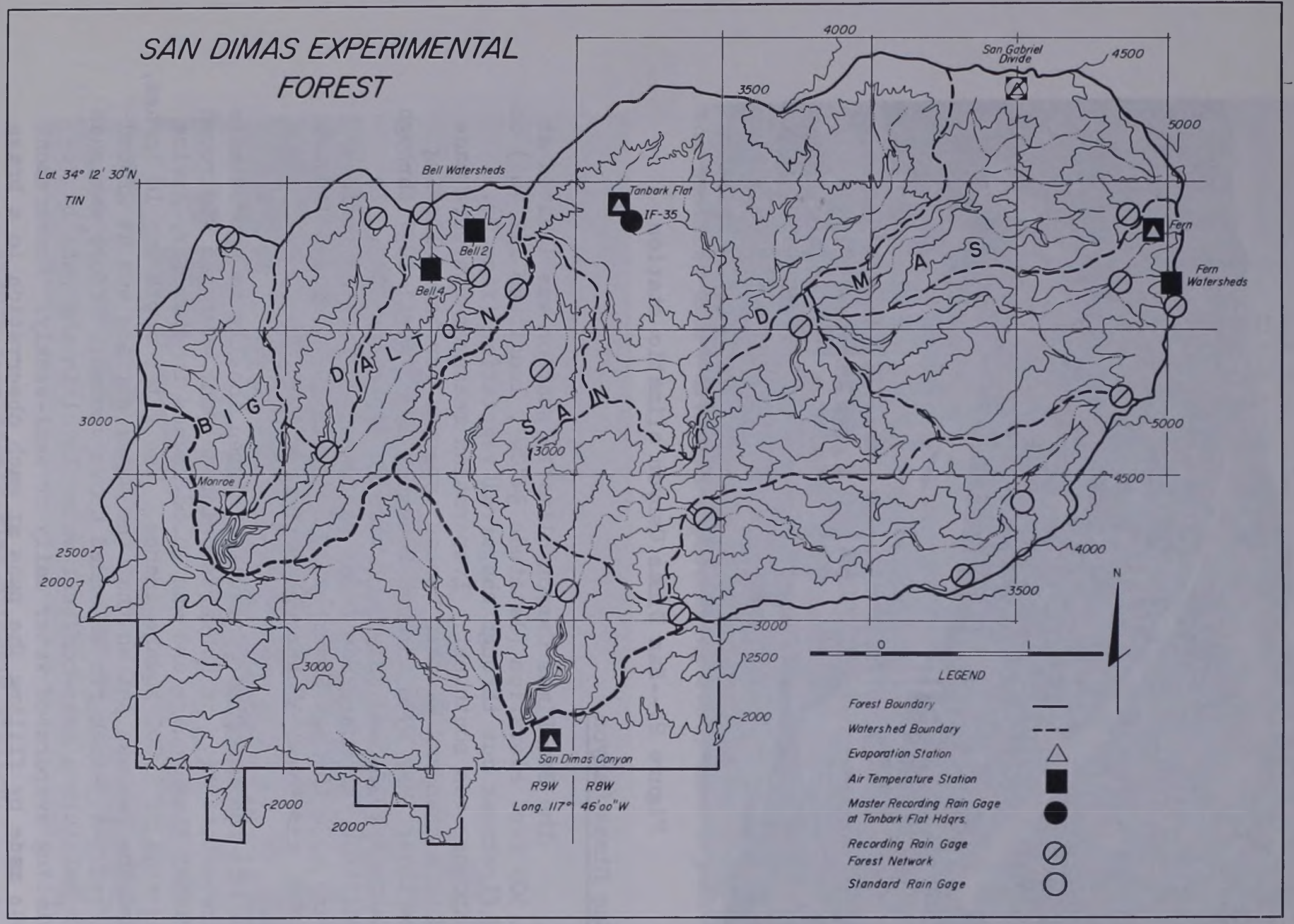

Figure 1.--San Dimas Experimental Forest in the San Gabriel mountains of southern California showing climatic stations and present rain gage locations.

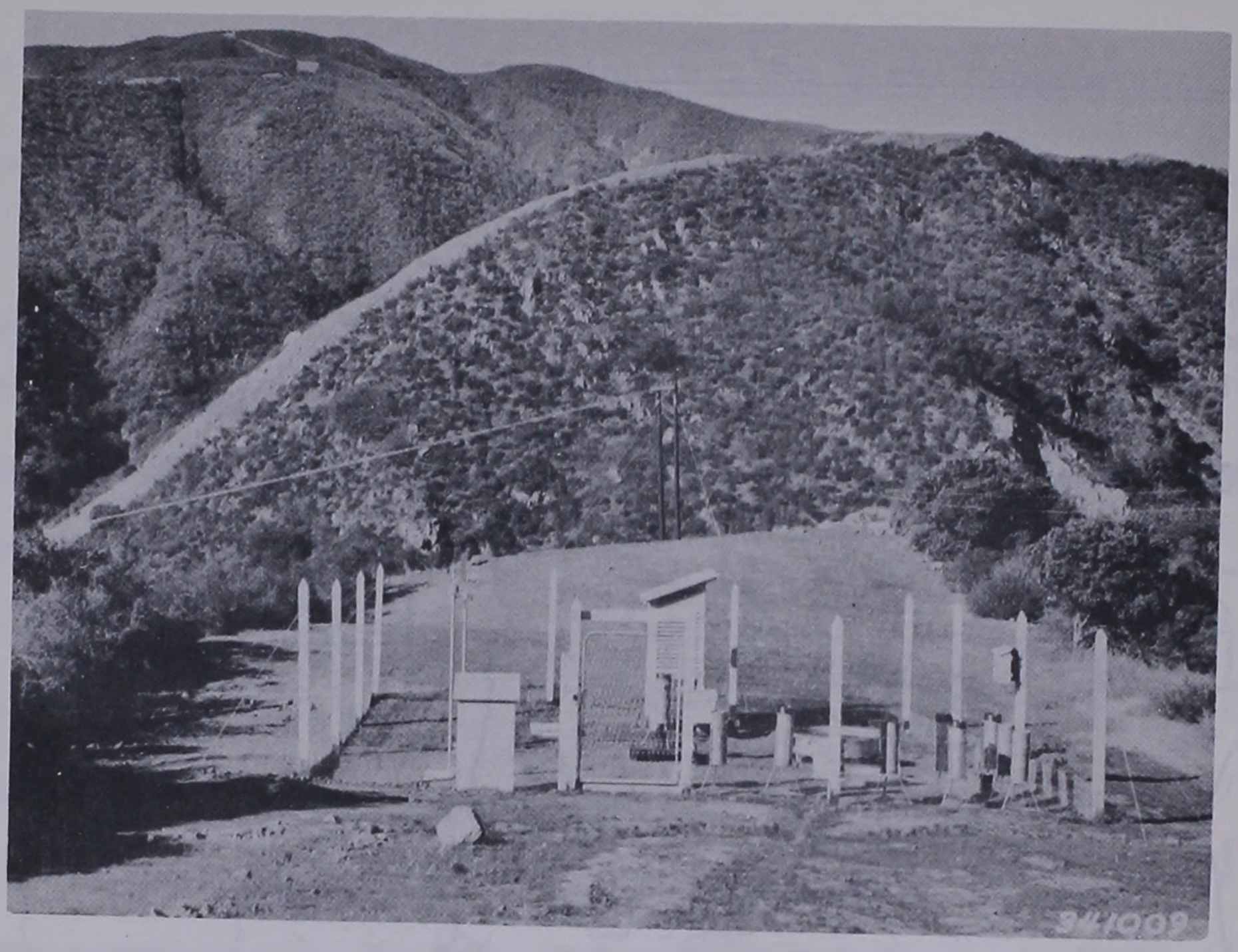

Figure 2.--San Dimas Canyon climatic station.

San Dimas Canyon

The San Dimas Canyon climatic station was located at 1,500 feet elevation (latitude 34°09', longitude 117°46') on a firebreak cut through chaparral vegetation (fig. 2). Exposure was southwest. Evaporation measurements were made with a standard Weather Bureau type pan for the following periods: May 1936 through November 1936, April 1937 through January 1938, and July 1938 through September 1943. In addition, a sunken San Dimas pan was used for the periods June 1936 through November 1936, April 1937 through January 1938, and May 1938 through September 1940.

The San Dimas pan was designed locally to approximate characteristics of Rohwer's Colorado pan. Our pan was round rather than square and was 35.68 inches in diameter, giving an area of 1,000 square inches. The water depth was 18 inches, and the pan was set so that the water surface was at ground level. A 3-inch rim extended above ground. Effort was made to maintain a near-constant water level in the pans by replacing evaporated water daily or semi-weekly. Measurement was made by filling the pans at each observation to a brass index point in the center of the pan. Water was added by a graduate calibrated on the basis of pan area and water depth.

Tanbark Flat

The Tanbark Flat climatic station was first located just above the field headquarters of the San Dimas Experimental Forest at 2,725 feet elevation (latitude 34°12', longitude 117°46') in an opening in chaparral vegetation with a south exposure. Evaporation measurements were made with a standard Weather Bureau type pan from June 27, 1935 through October 10, 1938 and by a San Dimas type pan from June 27, 1935 through September 8, 1938. May 13, 1937 a new station was installed, 1,100 feet north by west of the first station, at 2,800 feet elevation with a southern exposure in an area surrounded by shrub vegetation (fig. 3). On July 12, 1938 Weather Bureau type and San Dimas type evaporation pans were installed at the new station. The Weather Bureau pan is still in operation, but the San Dimas pan was discontinued January 31, 1941. In addition, a Taylor shallow black pan evaporimeter was installed May 11, 1937 and operated until October 20, 1954. This was a flat black pan 1 inch deep mounted on a Fergusson weighing rain gage mechanism. The pan was 25.298 inches in diameter, providing an evaporation surface 10 times the area of a standard 8 inch rain gage. Therefore, the weighing mechanism operating in reverse could record minute water losses, the smallest chart division representing 0.005 inch depth.

Figure 3.--Tanbark Flat climatic station.

Evaporation data for the Weather Bureau type pan and the San Dimas type pan for the period July 1935 through June 1938 were interpolated for the new station from data obtained at the first Tanbark Flat climatic station on the basis of a comparison of data taken simultaneously at both stations.

San Gabriel Divide

The San Gabriel Divide climatic station was located at 4,350 feet elevation (latitude 34°13', longitude 117°43') in an opening in the chaparral on a point near the crest of a ridge (fig. 4). Exposure was due south. A standard Weather Bureau type evaporation pan was used for the period June 1936 through September 1936, August 1937 through November 1937, and May 1938 through September 1943. Records were interrupted at times during winter seasons by freezing temperatures and snow conditions.

Figure 4.--San Gabriel Divide climatic station.

Figure 5.--Fern Canyon climatic station.

Fern Canyon

The Fern Canyon climatic station was located at 5,100 feet elevation (latitude 34°12', longitude 117°42') in a small opening surrounded by chaparral vegetation (fig. 5). Exposure was south. The station and surrounding brush cover were destroyed by fire in November 1938. The area was fairly well revegetated by sprouting shrubs within the next 3 years. Evaporation measurements were made with a standard Weather Bureau type pan for the periods May 1937 through October 1937, April 1938 through July 1938, December 1938 through September 1940, and January 1942 through September 1943. Evaporation records during the winter season were interrupted frequently by freezing temperatures and snow conditions.

SAN DIMAS EXPERIMENTAL FOREST
San Dimas Canyon Climatic Station, Elevation, 1,500 feet

Evaporation Data

WEATHER BUREAU PAN

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - - - - - - - - - - - - - - Surface inches - - - - - - - - - - - - - - - - - -												
1935-36	--	--	--	--	--	--	--	6.87	8.73	9.69	8.68	7.65	--
1936-37	5.77	3.51	--	--	--	--	2.50	4.81	6.82	9.07	9.84	7.88	--
1937-38	5.96	3.13	2.20	3.69	--	--	--	--	--	8.08	8.62	7.21	--
1938-39	4.30	4.20	2.71	2.03	2.21	2.04	4.24	5.43	7.68	9.03	8.51	5.41	57.79
1939-40	4.28	3.71	3.06	1.00	1.53	3.83	3.22	6.46	6.92	9.48	8.73	6.71	58.93
1940-41	5.62	3.25	1.82	1.62	1.00	2.00	2.08	6.63	5.96	8.81	6.90	5.75	51.44
1941-42	3.93	3.66	1.74	2.27	2.63	3.86	2.98	5.95	6.83	9.82	8.60	6.27	58.54
1942-43	4.55	2.69	2.47	2.79	2.27	2.40	3.36	6.29	6.89	8.17	7.97	7.31	57.16
5-year mean[1/]	4.54	3.50	2.36	1.94	1.93	2.83	3.18	6.15	6.86	9.06	8.14	6.29	56.78

SAN DIMAS PAN

1935-36	--	--	--	--	--	--	--	--	7.58	8.31	7.92	5.27	--
1936-37	4.62	2.79	--	--	--	--	2.17	4.32	5.46	8.53	7.31	7.24	--
1937-38	4.91	2.85	1.91	2.59	--	--	--	4.00	6.14	8.22	7.85	7.06	--
1938-39	4.64	3.76	2.33	1.83	1.98	1.88	3.44	5.19	7.50	8.31	7.94	5.19	53.99
1939-40	3.84	3.04	2.53	.90	1.36	3.12	2.87	5.61	5.88	8.30	7.43	5.97	50.85

1/ 5-year mean for the years 1938 to 1943.

SAN DIMAS EXPERIMENTAL FOREST
Tanbark Flat Climatic Station, Elevation 2,800 feet

Evaporation Data--Weather Bureau Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - - - - - - - - - - - - - - Surface inches - - - - - - - - - - - - - - - - - -												
1934-35[1/]	--	--	--	--	--	--	--	--	--	10.29	9.61	8.06	--
1935-36[1/]	5.41	3.48	2.58	1.94	2.08	3.85	3.85	6.25	9.67	10.34	10.07	8.12	67.64
1936-37[1/]	5.78	3.66	2.68	2.27	2.06	3.92	3.92	6.02	8.12	10.77	10.47	8.22	67.89
1937-38[1/]	6.17	2.61	1.98	2.24	1.13	3.12	4.53	6.64	7.56	10.22	10.20	9.45	65.85
1938-39	5.62	6.00	3.26	2.78	2.89	3.96	5.26	5.53	7.89	9.56	11.58	8.32	72.65
1939-40	6.44	4.53	3.66	2.45	2.63	4.49	4.88	7.24	8.79	11.85	12.07	8.65	77.68
1940-41	6.96	4.00	2.00	1.50	1.71	2.77	3.35	6.61	6.82	10.19	8.06	7.42	61.39
1941-42	4.81	4.29	1.68	2.64	3.12	4.69	3.30	6.55	7.73	11.89	10.35	9.03	70.08
1942-43	6.10	4.12	3.42	3.32	3.15	3.22	4.41	6.77	7.14	9.91	9.38	9.14	70.08
1943-44	5.67	4.53	1.76	2.43	1.97	4.12	4.16	5.13	4.79	8.23	9.75	7.19	59.73
1944-45	5.66	2.37	2.43	2.32	2.26	2.95	4.90	5.56	5.55	9.75	8.50	7.58	59.83
1945-46	4.77	3.48	2.16	3.47	2.88	3.22	4.90	3.75	7.59	8.53	10.30	8.34	63.39
1946-47	5.08	2.50	2.24	3.03	2.75	3.06	4.53	5.49	6.36	11.36	8.86	8.28	63.54
1947-48	5.46	3.71	3.24	4.34	3.08	2.81	4.00	5.29	6.38	10.15	11.33	10.16	69.95
1948-49	5.76	5.04	2.75	2.11	1.94	3.05	4.65	4.84	7.02	9.10	9.51	8.90	64.67
1949-50	5.17	4.38	2.09	1.41	2.33	3.39	3.86	5.42	6.82	9.85	11.55	7.86	64.13
1950-51	7.58	4.40	3.18	1.85	2.53	4.43	3.23	6.22	7.02	10.90	10.98	10.10	72.42
1951-52	6.10	2.93	1.56	1.46	2.47	2.56	3.39	6.79	5.93	9.00	8.68	6.65	57.52
1952-53	5.87	2.19	1.43	2.41	3.16	3.51	3.45	5.53	6.54	10.29	9.32	7.76	61.46
1953-54	6.07	3.24	3.44	1.66	3.61	2.48	4.28	5.97	6.15	8.97	7.86	7.65	61.38
1954-55	5.96	3.43	1.94	1.35	2.40	3.88	4.50	4.43	6.13	8.64	9.49	9.25	61.40

Continued.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- Surface inches -												
1955-56	6.60	3.17	1.36	1.60	2.09	4.21	2.97	4.47	7.24	8.48	9.05	9.60	60.84
1956-57	4.14	5.16	3.53	1.35	1.59	2.57	3.73	3.66	6.48	9.53	9.84	8.29	59.87
1957-58	3.19	2.15	1.76	2.25	1.62	1.59	4.00	5.75	6.41	7.81	7.11	6.52	50.16
23-year mean	5.67	3.71	2.44	2.27	2.41	3.38	4.09	5.65	6.96	9.80	9.75	8.37	64.50

1/ The values during these years (excepting July, August, and September of 1938, for which there are direct data) were interpolated from data obtained at the "Old" Tanbark Climatic Station location on the basis of a comparison of later data taken simultaneously at both locations.

SAN DIMAS EXPERIMENTAL FOREST
Tanbark Flat Climatic Station, Elevation 2,800 feet

Evaporation Data--San Dimas Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - - - - - - - - - - - - - - Surface inches - - - - - - - - - - - - - - - - - -												
1934-35[1]	--	--	--	--	--	--	--	--	--	9.68	8.62	8.66	--
1935-36[1]	5.15	3.48	2.85	2.49	2.11	3.24	4.60	6.58	8.89	9.48	9.44	7.73	66.04
1936-37[1]	5.13	3.56	2.52	2.13	2.06	3.16	4.25	5.64	8.44	10.09	9.82	7.70	64.50
1937-38[1]	5.63	2.38	1.96	1.95	1.16	2.61	4.06	5.92	7.20	9.63	9.49	8.29	60.28
1938-39	4.89	5.06	2.59	2.57	2.88	3.03	4.52	5.33	7.68	9.44	10.22	6.63	64.84
1939-40	5.55	3.84	2.96	1.86	2.14	3.79	4.20	6.76	8.19	10.48	10.16	7.63	67.56
1940-41	5.95	3.58	2.18	1.61	--	--	--	--	--	--	--	--	--
5-year mean[2]	5.27	3.66	2.58	2.20	2.07	3.17	4.33	6.05	8.08	9.82	9.83	7.60	64.66

1/ The values during these years (excepting July, August, and September of 1938, for which there are direct data) were interpolated from data obtained at the "Old" Tanbark Climatic Station location on the basis of a comparison of later data taken simultaneously at both locations.

2/ 5-year mean for the years 1935-1940.

SAN DIMAS EXPERIMENTAL FOREST
Tanbark Flat Climatic Station, Elevation 2,800 feet

Evaporation Data--Taylor Black Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	Surface inches												
1936-37	--	--	--	--	--	--	--	--	10.30	12.07	12.04	10.89	--
1937-38	9.07	6.04	4.50	4.40	4.16	4.77	7.56	9.92	9.33	11.59	11.05	10.56	92.95
1938-39	7.26	8.81	6.29	4.25	3.08	6.73	8.19	6.60	9.67	12.21	11.32	8.55	92.96
1939-40	8.62	5.52	4.84	2.73	4.41	6.20	7.26	8.49	9.57	12.43	12.18	9.39	91.64
1940-41	8.65	5.61	5.42	2.76	2.44	3.88	5.46	6.82	8.40	11.41	9.30	8.52	78.67
1941-42	7.22	5.34	3.35	3.66	3.95	7.56	5.91	8.56	10.11	14.60	12.43	10.77	93.46
1942-43	7.59	5.31	4.70	4.43	4.33	4.00	5.72	9.17	9.45	12.25	11.30	11.51	89.76
1943-44	7.20	5.92	2.61	3.26	2.84	6.24	5.88	7.17	6.91	10.75	12.32	9.37	80.47
1944-45	7.38	3.35	3.69	3.32	3.12	4.28	7.58	7.14	7.04	11.83	11.36	9.24	79.33
1945-46	6.21	4.97	3.20	5.26	4.00	4.60	6.79	4.91	9.63	10.79	11.94	10.30	82.60
1946-47	5.65	3.00	2.90	4.16	3.43	4.30	5.75	7.05	7.94	12.75	10.57	9.93	77.43
1947-48	6.41	4.70	3.51	4.99	4.22	4.00	5.54	6.85	7.98	12.64	12.86	11.23	84.93
1948-49	6.72	5.67	2.75	2.43	2.35	4.27	6.46	6.37	9.00	11.05	11.38	10.84	79.29
1949-50	6,56	5,59	2,89	2,10	3.55	5.03	5.63	6.97	8.86	11.18	13.32	10.34	82.02
1950-51	9.16	6.21	4.12	2.59	3.39	5.82	4.40	8.18	9.22	12.24	12.08	11.84	89.25
1951-52	7.40	3.61	2.01	1.73	3.37	3.41	4.81	8.60	7.48	10.50	10.51	8.46	71.89
1952-53	7.27	2.68	1.98	3.28	4.41	5.33	4.92	7.40	7.86	11.31	10.96	9.86	77.26
1953-54	7.41	4.09	4.51	2.36	4.67	3.46	5.82	7.70	7.65	10.04	9.25	9.10	76.06
17-year mean	7.40	5.08	3.72	3.39	3.63	4.93	6.10	7.52	8.59	11.74	11.42	9.99	83.51

SAN DIMAS EXPERIMENTAL FOREST
San Gabriel Divide Climatic Station, Elevation 4,350 feet

Evaporation Data--Weather Bureau Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - Surface	inches - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
1935-36	--	--	--	--	--	--	--	--	9.21	9.85	9.46	8.50	--
1936-37	--	--	--	--	--	--	--	--	--	--	10.34	8.20	--
1937-38	6.81	3.60	--	--	--	--	--	9.06	7.77	10.35	8.71	8.01	--
1938-39	5.07	4.88	3.03	2.29	2.58	3.87	6.06	6.61	9.15	10.74	11.30	7.06	72.64
1939-40	6.75	4.53	2.93	1.93	2.05	4.72	5.08	7.69	9.78	10.51	10.61	7.49	74.07
1940-41	5.86	3.67	2.00	1.15	1.00	2.11	3.20	6.35	6.18	9.76	8.05	7.24	56.57
1941-42	5.08	3.49	1.55	2.68	2.56	4.33	2.58	6.49	8.57	11.74	10.50	9.00	68.57
1942-43	6.52	4.19	3.99	3.50	3.03	2.73	4.38	7.40	7.31	9.84	8.87	7.74	69.50
5-year mean 1/	5.86	4.15	2.70	2.31	2.24	3.55	4.26	6.91	8.20	10.52	9.87	7.71	68.28

1/ 5-year mean for the years 1938-43.

SAN DIMAS EXPERIMENTAL FOREST
Fern Canyon Climatic Station, Elevation 5,100 feet

Evaporation Data--Weather Bureau Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - - - - - - - - - - - - - - Surface inches - - - - - - - - - - - - - - - - - -												
1936-37	--	--	--	--	--	--	--	7.70	9.15	10.45	11.06	9.10	--
1937-38	6.70	--	--	--	--	--	3.28	4.68	7.81	7.34	--	--	--
1938-39	--	--	4.50	2.00	2.00	4.14	6.94	8.58	9.88	11.04	11.21	6.51	--
1939-40	8.64	5.68	4.16	1.53	1.11	4.46	5.24	8.66	10.92	11.15	11.11	7.35	80.01
1940-41	No records ----------												
1941-42	--	--	--	3.00	3.01	4.14	2.99	6.73	9.43	12.00	10.37	9.38	--
1942-43	6.45	4.07	3.60	3.35	3.91	3.05	4.73	7.92	7.71	10.61	8.75	8.59	72.74